Review Article

International Journal of Dental and Health Sciences
Volume 02,Issue 01

WORKING LENGTH DETERMINATION- THE SOUL OF ROOT CANAL THERAPY: A REVIEW

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ABSTRACT:

The determination of accurate working length is one of the most critical step in the endodontic therapy. The cleaning, shaping and obturation cannot be accomplished accurately unless the working length is determined precisely. Thus the predictable endodontic success demands an accurate working length determination of the root canal. This article reviews about working length determination and its clinical implications.

Keywords: Cemento-dentinal junction,Dentistry,Electronic apex locater,Radiographic tooth length, Stomatognathic system, Working length determination.

INTRODUCTION:

The triad in endodontic therapy comprises of total debridement of the pulpal space, proper cleaning and shaping of the canal space and three dimensional obturation of the root canal.The most important segment of endodontic treatment is canal preparation which can be accomplished by correct determination of the working length [1,2,3].The endodontic glossary defines working length as "the distance from a coronal reference point to a point at which the canal preparation and obturation should terminate". The significance of the working length are as follows:

1. The working length determines how far into the canal the instruments can be placed and worked.
2. It affects the degree of pain and discomfort which patient will experience following appointment by the virtue of over or under instrumentation.
3. If placed within correct limits, it plays an important role in determining the success of treatment.
4. When working length is short, it leads to apical leakage. Moreover, there is continued existence of viable bacteria which contributes to periradicular lesion and thus poor success rate.

Therefore it can be seen quite clearly that the calculation of working length should be performed with skill, using techniques that have been proven to give valuable and accurate results and by methods that are practical and efficacious.The ideal requirements for determining the working length of the tooth are accuracy, easy to

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perform, easily reproducible and should be confirmative.

HISTORICAL PERSPECTIVES:

In 1896 Dr. Charles Edmund Kells was the first to introduce the application of x-rays in dentistry. During 19th century, working length was usually calculated by placing the instrument in the canal and the point wherethe patient felt pain was recorded. In 1901, Dr. Weston A. Price called attention to incomplete root canal fillings as evidenced in radiographs. Price was suggested that radiographs should be used to check the accuracy of the root canal fillings.

In 1900's the popular opinion was that dental pulp extended through the tooth and end at the apical foramen and that the narrowest diameter of the apical portion of the root was precisely at the site where the canal exits the tooth at the extreme apex.These views fostered the then existing technique to calculate working length to the tip of the root on the radiographs" i.e. the radiographic apex" – as the correct site to terminate the canal.

In the 1920's considerable study of the apex of the tooth led Grove, Hatton, Blayney and Coolidge to offer reports that contradicted this position. Kuttler did the most comprehensive study in 1955 on the microscopic anatomy of the root tip. His study continued to regal the students of endodontic theory and practice and unquestionably it is one of the most important set of proper standards for sophisticated successful endodontic treatment.

VARIOUS METHODS FOR CALCULATING WORKING LENGTH:

a. Radiographic method

1. Grossman's Method
2. Ingle's Method
3. Kuttler Method
4. Best's Method
5. Bregman's Method
6. Bramante's Method
7. X-ray Grid System
8. Xero Radiography
9. Direct Digital Radiography

b. Non-radiographic method

1. Apex Finder
2. Audiometric Method
3. Tactile Method
4. Paper Point Evaluation Method
5. Electronic Apex Locators.

A. Radiographic method

Though used many years ago, still a number of excellent clinicians use the radiographic apex as the site of canal termination. Those who endorse this concept state that it is impossible to locate the cemento-dentinal junction (CDJ) clinically and that the radiographic apex is the only reproducible site available in this area. Grove, Green and Kuttler reported on a common finding that the apical foramen exits at a distance 1 – 3mm from the root tip [4,5]. The vertical position of the cement-dentinal junction (CDJ) varies with each tooth. It may be located 0.5 to 2 – 3mm from the radiographic apex, produces esthetically pleasing radiographs [6,7,8]

The position of the radiographic apex depends on several factors:

a. The angulations of the tooth
b. Position of the film
c. Holding agent for the film (finger, X-ray holder, hemostat, cotton roll)
d. The length of the X-ray cone
e. Horizontal and vertical positioning of the cone
f. The use of intentional distortion of the cone (for angled views)
g. Anatomic structures adjacent to the tooth & several other factors.

1. **Grossman's method[6]**

The original diagnostic radiograph is used to estimate the working length of the tooth from occlusal to root apex. This length is later verified by placing instruments to the estimated working length in the root canal and taking an instrumentation radiograph. The exact working length for each canal is determined by adjusting the length of insertion so the tip of the instrument ends 0.5mm from the root apex.

Step by step procedure

Initially the diagnostic file (usually no. 10-20 K file) that fits into the root canal is inserted through the access cavity with a slight wiggling motion to bypass any obstruction or debris and is gently teased along the entire canal length until it has been inserted to the estimated working length of the canal. A radiograph is taken to compare the exact position of the instrument in the root canal with the measure depth of insertion. If necessary the measured length is adjusted so that the instrument tip is inserted up to 0.5 mm from the apical exit of the root canal to the reference point on the crown of the tooth.

If the K-file is 1 mm longer or shorter of the radiographic foramen one should add or subtract the necessary length to obtain the root canal length, but if the differences are greater than 1 mm, one should make necessary adjustments on the file and take another radiograph.

By measuring the length of radiographic images of both the tooth and the measuring instruments as well as the actual length of the instrument, the clinician can determine the actual length of the tooth by a mathematical formula.

$$\text{Actual length of tooth} = \frac{\text{ALI} \times \text{RLT}}{\text{RLI}}$$

ALT -Actual length of tooth

ALI -Actual length of instrument

RLT -Radiographic length of tooth

RLI -Radiographic length of instrument

2. **Ingle's method [2]**

In order to establish length of tooth, a reamer or file with a rubber 'stop' on the shaft is needed. The exploring instrument size must be small enough to negotiate the total length of the canal.

Step by step procedure for Ingles method

i. Measure the tooth on the pre-operative radiograph

ii. Subtract at least 1 mm, which is for safety factor for possible image distortion or magnification.

iii. Set the instrument at this tentative working

iv. Place the instrument in the canal until the stop, in case the instrument is left at that level and the rubber stop readjusted to this new point of reference.

v. On the radiograph measure the difference between the end of the instrument and the end of the root. Add this amount to the original measured length; if the instrument through some oversight has extended beyond the apex subtract the difference.

vi. From this adjusted length of the tooth subtract about 1 mm "Safety factor" to conform the instrument within the apical termination of the root canal at the CDJ.

vii. Set the endodontic ruler at this new corrected length and readjust the stop on the exploring instrument.

viii. A confirmatory radiograph of the new adjusted W.L. is highly desirable because of the possibility of radiographic distortion, sharply curving roots and operator measuring errors.

3. Kuttler's method [4,5]

According to Kuttler the narrowest diameter is definitely not at the site of exit of the canal from the tooth but usually occurs within the dentin, just prior to the initial layers of cementum. He referred to this position as the '*minor diameter*' of the canal (apical constriction).

In 1955 Kuttler measured the distance among 20 different anatomic positions these calculations were for e.g. – from major to minor diameter or width of either diameters. The diameter of the canal at the site of exiting from the tooth was found to be approx twice as wide as the minor diameter this is the "*major diameter*".

Technique for calculation of working length: Before starting endodontic treatment the dentist must identify the probable i.e.

- The canal configuration present
- The estimated length of the root (s)
- The site of exiting of the canal (s)
- The estimated width of the canal (s)

This is done by analyzing the pre-op radiograph available using both straight – for site (s) of exiting, root (s) length, canal (s) width & angled views – for canal configuration (s) and sites of exiting.

The calculations dealing with the site of exiting of the canal (s) length & widths will help to identify the major and more often the minor diameter. The calculations dealing with the widths & length is valuable in making the calculation for working length.

The basis for this method's value is the measurement provided by Kuttler relating to the distance between the major diameter (site of exiting of the canal) and the minor diameter (i.e. the CDJ). In younger patients the distance between these two positions is approx 0.5 mm and in older patients due to increased build-up of cementum the distance is approx. 0.67 mm. Using the radiograph the dentist must locate the major diameter and then interpolate the position of the minor diameter or locate the minor diameter by seeing the funneled shape into the tooth from the site of the exiting.

Step-by-Step technique for calculation of working length by Kuttlers method:

- Using the information from the straight and angled radiographs about the expected canal configuration prepare a correct access cavity. Remove whatever pulp tissue and debris needs to be removed prior to taking the length.
- Locate the major diameter and minor diameter on the pre-op x ray. In some cases the exact site may not be seen, only that the radiolucent line of the pulp canal space stops near the tip of the root.
- Estimate the length of the root (s) either by measuring the length with a –mm – ruler on the pre-op radiograph or using the tables in the opposite page.
- Estimate the width of the canals (s) on the radiograph. If the canal estimates is narrow, consider using a size 10 or 15 file, if average select – a size 20 or 25 file, if wide choose a size 30 or 35, if very wide choose size 50 or larger.
- Using the file selected by step (iv) Set the stop for the W.L. according to the measurement estimated in step (iii), Place the file in the access cavity and take an initial radiograph if the file seems to stop at a length that could be accurate stop and take a radiograph rather than force the file into the periapical tissues.
- If the file appears too long or too short by more than 1 mm from the minor diameter make the interpolation and use that as the calculated working length.
- If your file reaches the major diameter exactly, subtract .5mm from the length if the patient is 35 years old or younger, reduce .67 mm from that length if the patient is older.
- If the file reaches the site that you believe is the minor diameter use that as the calculated working length. If it is obvious that a great deal of cementum has been deposited at the root tip, subtract a greater amount from the site of the major diameter to rectify the increased distance.

4. Best's method [6,7]

In 1960 BEST described a technique for determining the tooth length. In this method a steel pin measuring 10 mm is fixed to the labial surface of the root with utility wax keeping the pin parallel to the long axis of the tooth and a radiograph obtained. The radiograph is then carried to a gauge, which would indicate the tooth length.

5. Bregman's method [6,7]

It is a method in which 25 mm length flat probes are prepared and each has a steel blade fixed with acrylic resin as a stop, leaving a free end of 10 mm for placement into the root canal? This probe is place in the tooth until the metallic end touches the incisal edge or cusp tip of the tooth. Then a radiograph is taken. In the radiographic image the following is measured.

ALT-Apparent length of the tooth (as seen in the radiograph)

RLI-Real length of the instrument

ALI-Apparent length of the instrument

Now RLT (Real length of the tooth) is calculated from the formula.

RLT-ALI x ALT / RLI

6. Bramante's method [6,7]

Bramante described another method to determine tooth length. He employed stainless steel probes of various calibers& Lengths. These were bend at one end at right angel and this bend is inserted partially in acrylic resin in such a manner that its internal surface is in flush with the resin surface contacting the tooth surface. The probe is introduced into the root canal so that the resin touches the incisal edge or cusp tip taking care to see that the bend segment of the probe would be parallel to the mesio-distal diameters of the crown thus making it possible to visualize it on the radiograph. Then the tooth is radiographed. In this radiograph the reference points are as follows.

A-Internal angle of intersection of incisal U radicular probe segment.

B-Apical end of the probe

C-Tooth apex

Measuring the radiographic image length of the probe. A-B, measuring the radiographic image length of the tooth from A to C and then measuring the real length of the probe.

Now the following equation is applied

CRD-Real tooth length

CRS-Real tooth length

CAD-Tooth length in radiograph

CAS-Instrument length in radiograph

CRD-CRS x CAD / CAS

Measuring the distance between the apical end of the probe and the tooth apex in the radiograph. This measure is either added or diminished to obtain the correct length of the tooth. This is somewhat similar to that described by Ingle.

7. X-ray grid system

Everett & Fixott in 1963 designed a diagnostic X-ray grid system for determining the length of the tooth. The diagnostic X-ray grid designed consists of lines 1 mm apart running lengthwise and cross-wise. A heavier line to make the reading easier on the radiograph accentuates every fifth millimeter.

Enameled copper wires are placed in plexi-glass and fixed to a regular periapical film. The grid is taped to film to lie between the tooth and film during exposure so that the pattern becomes incorporated in the finished film. The incorporated grid is used for accurate measurement of working length.

8. Xeroradiogrphy

Xeroradiography is a highly accurate electrostatic imaging technique that used a modified xerographic copying process to record images produced by diagnostic x-rays. Xero-radiography records images produced by x-radiation but differs from conventional radiography in that it does not require wet chemicals or dark room for processing.

In endodontics, Xero-radiographs permit better visualization of pulp chamber morphology, root canal configuration and root outline. This is especially evident in maxillary molars and pre molars, in which zygomatic arch and maxillary sinus super-impositions will hinder accurate visualization of dental structures. The lamina-dura is also clearly observed. A dental Xero-radiograph is also a useful diagnostic tool in determining root canal length. It has been stated that although there is no diagnostic difference between Xero-radiography and conventional radiography in determining the actual length of root canals, Xero-radiographic images of the fire for determining length are sharper and can be measured faster.. These might be useful in detecting carious lesions, especially proximal surface caries of adult and primary teeth.

According to Macro in 1984, Xeroradiography gave closer to accurate results in measurement compared to conventional radiographs.

9. Direct digital radiography or radio-visiography

A new radiographic system called DDR digitizes ionizing radiation. This system consists of a programmed computerized receiver that processes signals from an intra-oral sensor that is stimulated by x-rays from a standard dental machine. The computer-monitorised image then appears immediately upon the video monitor much like that in a large regular radiograph. This image may then be varied in size (zoom in for enlargement), in contrast (gradations of grey) and finally it can be printed out. The image can also be stored in computer for alter recall. Two of the earlier models of the DDR system are the RVG (Radio - Visiography) developed by Dr. Francis Mouyan, a French dentist and VIXA (Video imaging X-ray application).

B. Non-radiographic methods

1. Apex finder

M.M.Negm in 1982 introduced a novel method of determining the length of root canal without the use of radiographs. The new instrument apex finder is used to locate the apex as well as measuring the root length. The application of this method is based on insertion of a fine plastic tapered bared shaft through a beveled tube into the root canal.

When resistance to withdrawl is felt which indicates that some barbs have engaged the apical margin, the shaft is marked at the level of the cusp tip. The distance between the mark and the barbs, which caused the resistance, is measured.

2. **Audio metric method**

It is based on the principle of electrical resistance of comparative tissue using a low frequency oscillation sound to indicate when similarity to electrical resistance has occurred by a similar sound response. By placing an instrument in the gingival sulcus and including an electric current until sound is produced and then repeating this by placing an instrument through the root canal until the same sound is heard, one can determine the length of the tooth.

3. **Tactile method**

The experienced clinician develops a keen tactile sense and can gain considerable information from passing an instrument through the canal. Following access, when interferences in the coronal third of the canal are removed, the observant clinician can detect a sudden increase in resistance, as a small file approaches the apex. Careful study of the apical anatomy discloses two facts that make tactile identification possible.

i. The unresorbed canal commonly constricts just before exiting the root .

ii. It frequently changes course in the last 2-3 mm. Both structures apply pressure to the file. A narrowing presses more tightly against the instrument, whereas a curvature deflects the instrument from a straight path. Both consume energy and sensitive instrument with which the experienced clinician can accurately determine passage through the foramen. At this point, it also has access to pass through the apical accessory canal.

4. **Paper point evaluation**

The paper point may be used to detect bleeding or apical moisture. A bloody or moist tip suggests an over extended preparation. Further assessment of the apical preparation and working length should be made. The point of wetness often given an approximate location to the actual canal end point. A wet or bloody point may also indicate that the foramen has been zipped or the apex perforated during preparation. These conditions would require additional canal shaping in addition to adjustment of working length.

5. **Electronics apex locator**

Although the term “apex locator” is commonly used and has become accepted terminology, it is a misnomer. These devices attempt to locate the apical constriction, the cemento-dentinal junction, or the apical foramen. They are not capable of routinely locating the radiographic apex. In 1918, Custer was the first to report the use of electric current to calculate working length. The scientific basis for apex locators originated with research conducted by Suzuki in 1942. In 1960, Gordon was the second to report the use of a clinical device for electrical measurement of root canals. Sunada adopted the principle reported by Suzuki and was the first to describe the detail of a simple clinical devise to measure working length in patients. He used a simple direct current ohmmeter to measure a constant resistance of 6.5 kilo-ohms between oral mucous membrane and the periodontium regardless of the size or shape of the teeth. The device used by Sunada in his research became the basis for most apex locators.

All apex locators function by using the human body to complete an electrical circuit. One side of the apex locator's circuitry is connected to an endodontic instrument. The other side is connected to the patient's body either by a contact to the patient's hand. The electrical circuit is completed when the endodontic instrument is advanced apically inside the root canal until it touches periodontal tissue. The display on the apex locator indicates that the apical area has been reached. This simple and commonly accepted explanation for the electronic phenomenon has been challenged. It would be useful clinically to use the apical constriction as the ideal apical foramen. Consideration should also be given to using – 0.5 to 0.0 m as the most clinically ideal error tolerance.

Classification and Accuracy of Apex Locators:

The classification of apex locators presented here is a modification of the classification given by McDonald. This classification is based on the type of current flow and the opposite to the current flow, as well as the number of frequencies involved.

First-Generation Apex Locators- First – generation apex locations devices, also known as "resistance apex locators", measure opposition to the flow of direct current or resistance. Eg- sono-explorer.

Second-generation apex locators - Second-generation apex locators, also known as "impedance apex locators", measure opposition to the flow of alternating current or impedance.

There is another issue: not all apex locators incorporate the same degree of sophistication in electronic circuitry that adjusts its sensitivity to compensate for the intracanal environment or indicates on its display that it should be switched from a "wet" to a "dry" mode or vice versa. Eg- Apex finder, Endo Analyzer.

Third –Generation Apex Locators- The principle on which "third-generation" apex locators are based "comparative impedance".Since the impedance of a given circuit may be substantially influenced by the frequency of the current flow, these devices have been called "frequency dependent". Eg- Endex.

Fourth- Generation Apex Locators- The apex locaters are similar to Impedance-type because it measures the impedance of the tooth at two different frequencies. As the file is advanced apically, the difference in the impedance value begins to differ greatly with maximum difference at the apical area.

Fifth-Generation Apex Locators- These were developed in 2003. It measures the capacitance and resistance of the circuit separately. It is supplied by diagnostic table that includes the statistics of the values at different positions to diagnose the position of the file. Devices employing this method experience considerable difficulties while operating in dry canals.

Sixth-Generation Apex Locators-The sixth generation Adaptive Apex Locator overcomes as the disadvantages of the popular apex locators IVth generation low accuracy on working in wet canals, as well the disadvantages of devices Vth generation difficulty on working in dry canals and necessarily of compulsory, additional wetting. Adaptive Apex Locator continuously defines humidity of the canal and immediately adapts to dry or wet canal. This way it is possible to use it dry and in additional wetted canals as well, canals with blood or exudates, canals with still not extirpated pulp.

Advantages of electronic apex locators

- Only method that can measure the apical foramen, not to the radiographic apex.
- Accurate
- Easy and fast
- Reduction of x-ray exposure
- Artificial perforation can be recognized
- Can be used in pregnant women – because of no risk of radiation
- Can used in patient with gagging reflex
- Can be used when dense zygomatic arch is over lapping the apices of upper molars
- Can be used unerupted impacted tooth over shadows the apex
- Patients who have a phobia of radiographic exposure.

Disadvantages of electronic apex locators

- Requires a special device
- Accuracy is influenced by the electrical conditions in the root canal
- Difficult in tooth with open apex
- Inconsistent results

Recent advances:

Tomography: Is a radiographic technique that "slices" teeth in thin sections. Computers subsequently reassemble the sections to generate a three-dimensional image. Dental anatomy including bucco-lingual curvatures shapes of the root canal spaces and location of the apical foramen (which is important in determining or calculating the working length) can be visualized in the third-dimension. Additional advantage in the elimination of angled radiographs; all angled views are captured in just one exposure.

Videography and Intra-Oral Cameras: intra-oral videography is an non-ionizing diagnostic imaging technique. Developers are using miniature colour CCD (charge coupled device) chips. With fiber optic probes to assemble video cameras small enough to transverse periodontal defects and identify vertical root fractures. These devices are useful in endodontics as they can display canal morphology as well aid in locating canal orifices. Perforations can be visualized by inserting the fiber optic probe down the suspected canal.These devices are connected to a computer that provides enhanced images for teaching and patient education.

DDR- Fourth generation DDR: one of the more recent additions to Trophy's fourth generation RVG systems is the capability of on screen point-to-point measurements using multiple additive points. This capability potentially allows for fast accurate working length estimation in roots demonstrating severe apical curvatures. The RVG on screen measurement utility allows for rapid additive multiple point measurement of digital images, automatically tallying the measurement points on screen to a tenth of a millimeter.

Empirically it was expected that multiple measurements along the curve of a canal would be more accurate than a straight-line measurement from the reference point to the apex. It was felt that if measurement points were able to closely follow the curve a truely estimate of the working length would be obtained.

CONCLUSION:

It can be concluded from the current article that electronic apex locater are not superior to the radiograph in determining the working length. Thus long term follow up studies evaluating post-operative success comparing radiographic and non-radiographic methods are needed to appreciate the best method of working length determination in endodonitics.

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